

Appl. No. 09/943,843
Amdt. dated January 21, 2004
Preliminary Amendment

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REMARKS/ARGUMENTS

Claims 1, 2 and 4-13 are pending. Claims 1, 2, 4, 5, 8, 12, and 13 have been amended. Claim 3 has been canceled. No new claim has been added. No new matter has been added.

Claims 1 and 2 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Hobbs et al. Applicants traverse the rejection. The present inventors have solved a long felt need of finding an adequate replacement for the silicon oxide as the gate insulation material of choice. The claimed invention relates to reducing or controlling the current leakage that results from the diffusion of conductive elements from a gate electrode to a gate insulation layer. This current leakage problem becomes more and more serious as the devices shrink, and thinner and thinner gate oxides need to be used. Generally, it is believed that silicon oxide can no longer be used effectively as the gate insulation layer if its thickness is decreased to 2 nm or less, as explained in the background of the present application (see page 1). This is also supported by an articles published on August 6, 2001, in Electronic Design, entitled, "Labs Investigate New Materials to Boost IC Speeds," by Lisa Eccles, which is enclosed.

Without overcoming this problem, the semiconductor devices can no longer be made smaller and faster in the future. Many considered this to be a highly important problem that must be solved. Accordingly, highly skilled researchers around the world have devoted years of research, hoping to find a solution to this problem.

Likewise, the present inventors conducted an extensive research to find a solution to the above problem. The present inventors focused their research on titanium oxide which is one of many candidates currently being studied to replace the silicon oxide in the future devices. The problem associated with the use of titanium oxide however, is its relatively high current leakage, particularly when it is used as a thin layer (e.g., 3 nm) (see page 2, first paragraph of the specification). Partly due to this concern, many currently believe hafnium to be more suited for the future devices.

Nevertheless, after extensive research, the present inventors discovered a solution to current leakage problem of titanium oxide. They discovered that when titanium oxide (gate

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insulation) is used in conjunction with ruthenium oxide or iridium oxide (gate electrode), the diffusion of conductive elements is significantly reduced (see Figs. 2-9). The present inventors discovered that the diffusion prevention characteristics improved even more when the titanium oxide is configured as a rutile structure. Accordingly, the present inventors have solved a long felt need of finding an adequate replacement for the silicon oxide. This problem was solved by discovering an unexpected benefit of combining the titanium oxide and ruthenium oxide (or iridium oxide) in such a way to obtain improved diffusion blocking characteristics.

Claim 1 recites, "...a gate insulation film formed on one major surface of said semiconductor substrate and including titanium oxide; and a gate electrode film formed in contact with said gate insulation film, said gate electrode film having a dual function of being an electrode and a diffusion barrier, said gate electrode film being configured to minimize diffusion of conductive elements into said gate insulation film to reduce a current leakage via the gate insulation film, said gate electrode film including ruthenium oxide or iridium oxide, wherein said titanium oxide is in the form of a crystal of rutile structure, wherein said gate electrode film and titanium oxide cooperate to reduce the diffusion of conductive elements of said gate electrode into said gate insulation film, so that the diffusion of the conductive elements of said gate electrode is less than that of when said gate electrode comprises Si, W, WSi₂, Mo, MoSi₂, Ti, or TiN."

Hobbs does not disclose or suggest the features recited above. As the Examiner noted that Hobbs disclose a titanium dioxide gate dielectric 62 that is 5-20 nm in thickness and is not directed to controlling the diffusion of conductive elements. It is directed to providing a device with a metal gate electrode rather than the conventional polysilicon gate electrode. Hobbs lists numerous possible candidates for gate oxides and even more numerous possible candidates for gate electrodes, without any regard as to their feasibilities.

Hobbs is not directed to the current leakage problem in question. Accordingly, a person skilled in the art would not look to Hobbs to solve the long felt need that was solved by the present inventors. Therefore, claim 1 is allowable.

Claim 2 recites, "...a gate insulation film formed on one major surface of said semiconductor substrate and including titanium oxide; and a gate electrode film formed in

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contact with said gate insulation film, said gate electrode film having a dual function of being an electrode and a diffusion barrier, said gate electrode film being configured to minimize diffusion of conductive elements into said gate insulation film to reduce a current leakage via the gate insulation film, said gate electrode film including ruthenium oxide or iridium oxide, wherein film thickness of said gate insulation film is greater than about 0.9 nm and less than about 3 nm..."

Applicants note that Hobbs specifies the thickness of the titanium dioxide gate dielectric 62 as being 5-20 nm, the lower limit being 5 nm. This is probably because Hobbs thought that titanium oxide with its current leakage problem could be used at a thickness less than 5 nm, much less at 3 nm or less, as recited in claim 3. Therefore, Hobbs does not disclose or suggest the features recited in claim 2. Claim 2 is allowable.

Claims 3-7, 12, and 13 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Hobbs in view of Tsunashima. Applicants respectfully traverse the rejection. Tsunashima does not remedy the deficiencies of Hobbs as set forth above. Claim 3 has been canceled.

Claim 4 recites, "...a gate oxide film formed on one major surface of said semiconductor substrate, said gate oxide film being titanium oxide and having a given crystal structure; and a gate electrode formed over said gate insulation film, said gate electrode including a conductive oxide layer and a metal layer, said conductive oxide layer being provided between said gate oxide film and said metal layer, wherein said gate oxide film is greater than about 0.9 nm and less than about 2 nm in thickness."

Hobbs does not disclose a gate electrode comprising a conductive oxide layer and a metal layer, in the manner recited. The Examiner states that Hobbs discloses the recited gate electrode at col. 5, lines 12-30. At that section, Hobbs merely lists a laundry list of possible gate electrode materials and states that a combination thereof may be used. The combination appears to refer to a mixture of material rather than a dual gate electrode structure, in the manner recited. Even if the dual gate is disclosed, Hobbs does not teach providing the conductive metal oxide between the gate oxide film and the metal layer since this arrangement is provided to solve the current leakage problem, the problem to which Hobbs is not directed to. Tsunashima does not remedy this deficiency of Hobbs. Claim 4 also recites a gate oxid that is less than 2 nm in

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thickness. The device disclosed in Hobbs is not suitable for such a thin gate oxide layer. Claim 4 is allowable.

Claim 5 depends from claim 4 and is allowable at least for this reason.

Claim 12 recites, "...a gate insulation structure including of a first gate insulation film formed over said semiconductor substrate and including silicon oxide or titanium silicate and a second gate insulation film formed over said first gate insulation film and including titanium oxide; and a gate electrode film formed in contact with said gate insulation structure and including ruthenium oxide or iridium oxide, wherein film thickness of said second gate insulation film is greater than about 0.9 nm and less than about 2 nm." Neither references disclose a gate insulation structure in the manner recited. Claim 12 is allowable.

Claims 8, 9, and 11 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Hobbs in view of Gilbert. Applicants respectfully traverse the rejection. Claim 8 recites, "...a titanium oxide gate insulation film formed on one major surface of said semiconductor substrate and being no more than about 2 nm in thickness; a gate electrode including conductive oxide film and a metal film, said conductive oxide film being in contact with said gate oxide and configured to serve as a diffusion barrier to prevent diffusion of an element into said titanium oxide to reduce a current leakage via said titanium oxide film; a first capacitor electrode formed on said one major surface of said semiconductor substrate; a capacitor insulation film formed in contact with said first capacitor electrode and exhibiting a high dielectric constant or ferroelectricity; and a second capacitor electrode formed in contact with said capacitor insulation film, wherein said titanium oxide is provided with a given crystal structure, so that said titanium oxide cooperates with said gate electrode to reduce the diffusion of conductive elements of said gate electrode into said titanium oxide." Hobbs does not disclose or suggest above recited features. Gilbert does not remedy this deficiency. Claim 8 is allowable. Claims 9 and 11 depend from claim 8 and are allowable at least for this reason.

Claim 10 was rejected under 35 U.S.C. § 103(a) as being unpatentable over the combination of Hobbs, Gilbert, and Tsunashima. Applicants respectfully traverse the rejection. Claim 10 depends from claim 8 and is allowable at least for this reason.

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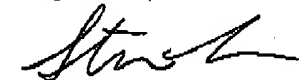
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CONCLUSION

In view of the foregoing, Applicants believe all claims now pending in this Application are in condition for allowance. The issuance of a formal Notice of Allowance at an early date is respectfully requested.

If the Examiner believes a telephone conference would expedite prosecution of this application, please telephone the undersigned at 650-326-2400.

Respectfully submitted,



Steve Y. Cho
Reg. No. 44,612

TOWNSEND and TOWNSEND and CREW LLP
Two Embarcadero Center, Eighth Floor
San Francisco, California 94111-3834
Tel: 650-326-2400
Fax: 415-576-0300
Attachments
SYC:syc
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